Chapter F-11
Sampling from Test Pits, Trenches, Accessible Borings, or Tunnels

11-1. Introduction

a. Accessible excavations. For certain geotechnical investigations, it may be necessary to provide excavations that are large enough to permit entrance by a person for inspection and sampling of subsurface materials in situ. Hvorslev (1949) called these excavations "accessible explorations." Accessible excavations are those excavations that are made with machinery other than conventional drilling and sampling equipment. These excavations include test pits or trenches, large-diameter borings, caissons, tunnels, shafts, drifts, or adits.

Accessible excavations expose large areas of subsurface materials that permit direct examination of the in situ conditions, observation of slope stability or groundwater conditions, fault evaluation studies, recovery of large undisturbed samples, in situ testing, installation of instrumentation, or evaluation of abnormalities. Accessible excavations also offer an excellent means for evaluating excavation methods or the effects of blasting while providing an opportunity to confirm data obtained from conventional boring and sampling programs. Accessible explorations may be the only practical method of obtaining accurate information regarding borrow materials, riprap and concrete aggregate, or test fills. The data in Table 11-1 suggest several types of accessible excavations as well as procedures and limitations for each.

b. Advantages and disadvantages. Before a decision is rendered that accessible excavations are needed as an integral part of the geotechnical investigation, the advantages and disadvantages of these excavations must be considered.

Accessible excavations provide the most reliable and detailed information of soil and rock along a specific horizontal or vertical line. Accessible excavations also permit direct examination, sampling, or in situ testing of the formation. Although the costs of accessible excavations are rather high, the costs are often small in comparison to construction costs where geologic information is meager or insufficient to forewarn of adverse conditions.

Examination, sampling, or in situ testing of the formation in accessible excavations is usually more expensive than for conventional in situ testing and sampling operations. The depths of accessible excavations are usually limited to about 6 to 9 m (20 to 30 ft) or to the water table. For greater depths, the costs and difficulties of excavating, cribbing, and pumping generally make accessible excavations impractical and uneconomical. Because longer periods of time are required to excavate the formation and to take the necessary safety precautions, disturbance caused by exposure of the formation may be greater for an accessible excavation than the disturbance caused by conventional sampling and in situ testing operations. The disturbance is caused by a change of water content, stress reduction, swelling or plastic flow, expansion of gas or air trapped in the soil, and oxidation or disintegration of the material.

c. Use. During the reconnaissance and feasibility stages of an investigation, representative, disturbed or undisturbed soil samples are necessary to estimate the engineering properties of materials to be used for construction of proposed embankment dams, canal linings, roads, etc. Unfortunately, representative samples of certain soils, including very soft cohesive soils, cohesionless soils, and gravelly soils, are very difficult and frequently impossible to obtain using conventional drilling and sampling techniques. The most feasible method for obtaining samples of these materials may be the use of test pits, trenches, shafts, or tunnels. Although only highly disturbed or remolded samples can sometimes be obtained, these excavations often yield excellent information regarding stratification and density of the formation as well as potential difficulties which may be encountered during construction. To fully utilize the data that can be obtained from accessible explorations, excavations should be designed and data collected under the supervision of geotechnical personnel who fully understand the purpose of the exploration program and how the data will be used for design and analysis.

11-2. Excavation

The depth of an accessible excavation dictates the method of excavation. Test pits and trenches may be excavated by hand or by conventional earth-moving equipment. Accessible borings may be drilled with special-purpose drilling rigs. Shallow pits dug to depths up to 1.2 m (4 ft) in stable soil usually require no shoring; for deeper excavations or pits in unstable soil, shoring must be used (EM 385-1-1). Excavations extending below the water table require control of the groundwater. In impervious or relatively impervious soils, groundwater can be controlled by pumping directly from a sump or drainage ditch in the pit. If the pit extends below the water table in sand or silt, dewatering by means of a well-point system may be necessary to ensure dryness and stability of the pit. If seepage forces are great, “blowouts” in the bottom or sides of the pit can result.

a. Test pits. Test pits are commonly used for exposing and sampling foundation and construction materials. The test pit must be large enough to permit detailed examinations of the material in situ to be conducted or to obtain large, undisturbed samples as required by the investigation. Typically, the plan view of the pit will be square, rectangular, or circular. The minimum dimensions of the pit are on the order of 0.9 by 1.5 m (3 by 5 ft) or 1.2 by 1.8 m (4 by 6 ft); it should be noted that these dimensions are net dimensions at the bottom of the excavation and do not include the space required for shoring or sloping the walls of the excavation in unstable or soft materials or for deep excavations.

Test pits may be dug by hand or by machine. Power excavating equipment, such as backhoes, trenching machines, draglines, clamshells, large-diameter bucket augers, or bulldozers, may be used for rough excavation of test pits to a distance of about 0.6 m (2 ft) from the proposed sample. The final excavation of samples must be carefully made with hand tools, such as picks, shovels, trowels, and buckets. Deeper pits must be started with sufficient dimensions to allow for shoring or sloping of the sides to prevent caving. The depth of the pit and the type and condition of the soil generally dictate the type of support system, such as sheeting, sheet piling, bracing, shoring, or cribbing, which is needed. General guidance for design of a support system is presented by Winterkorn and Fang (1975). Shoring must be installed progressively as the pit is deepened. The space between the walls of the pit and the support system should be kept to a minimum; this space may be backfilled with hay or excelsior.

Care must be exercised in excavating the area near the intended sample or test. The limits of the sample should be outlined with a pick and shovel. The material near the proposed sample should be excavated to a depth about 25 to 50 mm (1 to 2 in.) below the bottom of the intended sample. The excavated zone should be trimmed relatively level and be sufficiently large to allow adequate working space for obtaining the sample. A pedestal of soil, roughly the shape of the sample and about 25 mm (1 in.) larger in each dimension, should be left undisturbed for final trimming.

Excavated material should be placed at a horizontal distance from edge of the pit not less than the anticipated maximum depth of the pit. Excavated material should be placed in orderly fashion around the pit to facilitate logging of the material. Wooden stakes can be used to mark the depth of the excavated material. Samples for water content determination should be obtained in a timely manner to prevent drying of the material. Care should be taken to ensure that pits are properly ventilated to avoid carbon monoxide or poisonous gases. If necessary, a ventilation fan should be used to force air into the pit; the exhaust of any gasoline or diesel-powered equipment should be vented away from the pit.

b. Test trenches. Test trenches can be used to perform the same function as test pits but offer one distinct advantage, i.e., trenches provide a continuous exposure of the continuity and character of the subsurface material along a given line or section. Test trenches can be excavated with ditching machines, backhoes, bulldozers, or pans, depending upon the required size and depth of the trench. The minimum bottom width of a trench is about 0.6 to 0.9 m (2 to 3 ft), although this dimension is sometimes greater because of the use of power equipment, such as bulldozers and pans. As the trench is deepened, the sides must be sloped, step cut, or shored to prevent caving, similar to the procedures that must be used for excavating deep test pits. Final excavation in the vicinity of the intended sample must be performed carefully by hand.

c. Accessible borings. Although accessible borings, including shafts, tunnels, drifts, and adits, are not used extensively today because of the high costs of drilling operations, large accessible borings are sometimes required for inspection, sampling, or testing of selected strata by geotechnical personnel. The minimum diameter for the boring is about 0.6 m (2 ft), although larger dimensions may be necessary to provide ample working space. The depths of accessible borings may be considerably deeper than the depths of test pits or trenches. Because of the unknown conditions that may be encountered underground, a means for detecting poisonous gas should be provided before personnel are allowed to enter the accessible boring. Air should be ducted to the bottom of the hole.

Power-auger drills are frequently used to advance boreholes in most soils and soft rock (see Chapters 7 and 8). Steel-tooth single tube core barrels (calyx-coring equipment) are sometimes used when hard, stiff, or frozen soil or rock is encountered. A shot or calyx hole is drilled with a large heavy-walled steel tube that is equipped with a slotted bit made of mild steel. The top of the single-tube barrel is attached to heavy drill pipe by a thick circular head plate. The head plate has a hole at its center for the passage of drilling fluid. A deflector plate which is used to deflect the steel shot and drilling fluid to the periphery of the sample is located immediately below the head plate. A sludge barrel is sometimes attached above the core barrel to catch the cuttings. Two types of bits are commonly used. One type of bit consists of a second tube which is welded to the interior wall of the lower portion of the core barrel. The other type of bit consists of a heavy thick-walled pipe which is welded to the base of the barrel. Slots are cut into the bit to facilitate the movement of shot to the bottom and the outside of the bit. The thickness of the shot bit may vary from about 2.2 to 3.5 cm (7/8 to 1-3/8 in.). A core catcher is not provided. The core can be recovered by a lifting hook which is inserted into the sample through a hole that has been drilled in the center of the core. The core can also be recovered by using a special core lifter which has been attached to the core barrel; the core lifter works similarly to a conventional core catcher. The core barrel may also have provisions for placement of powder charges and conduit for blasting wires which may be necessary to separate the core from the formation.

During drilling operations, very hard steel shot are carried by the wash water through the annulus formed by the core and the core barrel to the slotted bit. As the barrel is rotated, shot is wedged beneath and around the bit and crushed into abrasive particles. Some of the shot may become embedded in the bit, which enhances the cutting action. The rate of feeding the shot and the flow of water in the borehole are critical factors. If too much shot is introduced, the bit will ride on the shot. If too little shot is used, the advancement of the borehole is inefficient. Likewise, too much water circulation will carry the shot away from the bit, whereas too little circulation will not remove the cuttings effectively. The cuttings are caught by the sludge barrel which is located above the corebarrel as they drop from suspension.

Casing must be installed in boreholes more than 1.2 m (4 ft) deep before anyone is allowed access to the hole (EM 385-1-1). Corrugated steel pipe is an economical, lightweight casing for relatively stable soils above the water table; in deep borings or in soft materials, heavy steel casing may be required. The borehole can be logged from cuttings as the hole is advanced or from samples or visual examination of the walls and bottom of the borehole at regular intervals. Windows may be cut in the casing for inspection, sampling, or testing of the materials along the sidewalls of the hole as required by the testing program.

An exploratory tunnel is usually rectangular shaped; minimum dimensions are typically of the order of 1.5 m (5 ft) wide by 2.1 m (7 ft) high, although these dimensions may be increased to meet the requirements of power-excavation equipment. The excavation of tunnels, which is usually very slow and expensive, may be conducted by mucking machines or by drilling and blasting. If drilling and blasting are used to advance the tunnel, the disturbed material caused by blasting should be carefully removed to ensure that undisturbed samples are obtained. The design of the support system for the tunnel should be made by a qualified, experienced professional.

11-3. Sampling and Testing

The following paragraphs describe various methods of obtaining soil samples from accessible excavations, including test pits, trenches, and accessible borings.

a. Undisturbed samples. Undisturbed samples are taken to preserve as closely as possible the in-place density, stress, and fabric characteristics of the soil. Although excavating a column of soil may relieve in situ stresses to some degree, it has been demonstrated that hand sampling of certain soils, such as stiff and brittle soils, partially cemented soils, and soils containing coarse gravel and cobbles, is perhaps the best and sometimes the only method for obtaining any type of representative sample. Large block samples of these materials are suitable for certain laboratory tests, although smaller samples should be used whenever the size of the sample does not adversely affect the test results. During handling and shipping of undisturbed samples, it is important to minimize all sources of disturbance including vibration, excessive temperature changes, and changes of water content.

(1) *Cylinder with advanced trimming*. Before sampling operations are begun, prepare the surface of the soil to be sampled as described in paragraph 11-2. After a pedestal of soil has been excavated, center the cutting edge of the sampling cylinder on top of the pedestal. To obtain a sample, trim the soil for a short distance below the cutting edge of the cylinder and then advance the cylinder by applying a slight downward pressure. Alternating trimming and advancing of the cylinder should be continued until the top of the sample extends approximately 12 mm (1/2 in.) above the top of the cylinder. During the trimming and sampling procedure, the sample should be trimmed as closely as possible to its final diameter without actually cutting into the intended sample; the final cutting of the sample is made by the advancement of the cutting edge of the cylinder without wiggling or change in direction. When sufficient material has been extended above the top of the cylinder, the sample should be cut from the pedestal of soil below the bottom of the cylinder, trimmed flush at both ends of the cylinder, and sealed for shipment to the laboratory.

The GEI sampler (Figure 11-1) incorporates the advanced trimming technique for obtaining a soil sample. The unique feature of the GEI device is a tripod holder that minimizes wiggling or change of direction during the advancement of the tube. Marcuson and Franklin (1979) reported that very high-quality samples of dense Savannah River sand were obtained by using the GEI sampling apparatus. The test data indicated that although only modest differences in sample densities existed between samples obtained with the GEI sampler and a fixed-piston sampler, a dramatic difference in resistance to cyclic loading was observed. Marcuson and Franklin concluded the differences of cyclic strengths were due to better preservation of the in situ structure.

(2) *Block or cube samples*. To obtain a cube or block sample, prepare the surface of the soil to be sampled as described in paragraph 11-2. Excavate a pedestal of soil that is slightly larger than the dimensions of the box or container into which the sample is to be placed. A knife, shovel, trowel, or other suitable hand tools should be used to carefully trim the sample to about 25 mm (1 in.) smaller than the inside dimensions of the box. As the sample is trimmed to its final dimensions, cover the freshly exposed faces of the sample with cheesecloth and paint with melted wax to prevent drying and to support the column of soil. After the block of soil has been trimmed but before it has been cut from the underlying material, place additional layers of cheesecloth and wax to form a minimum of three layers, as presented in ASTM D 4220-83 (ASTM 1993). A 1:1 mixture of paraffin and microcrystalline wax is better than paraffin for sealing the sample. A sturdy box should be centered over the sample and seated. Loose soil may be lightly tamped around the outside of the bottom of the box to align the box with respect to the soil sample and to allow packing material such as styrofoam, sawdust, or similar material to be placed in the voids between the box and the soil sample. Hot wax should not be poured over the sample. After the packing material has been placed around and on top of the sample and the top cover for the box has been attached, cut or shear the base of the sample from the parent soil and turn the sample over. After the sample has been trimmed to about 12 mm (1/2 in.) inside the bottom of the box, the bottom of the sample should be covered with three alternating layers of cheesecloth and wax. The space between the bottom of the sample and the bottom of the box should be filled with a suitable packing material before the bottom cover is attached. The top and bottom of the box should be attached to the sides of the box by placing screws in predrilled holes. The top and bottom should never be attached to the sides of the box with a hammer and nails because the vibrations caused by hammer blows may cause severe disturbance to the sample. Figure 11-2 shows block samples in various stages of trimming and sampling.

Tiedemann and Sorensen (1983) suggested an alternative method for trimming block samples. They reported that soils sampled successfully using the chain-saw method included a weathered shale between layers of sound sandstone and a highly slickensided, desiccated fat clay; they stated that it had not been possible to sample either of these soils using conventional hand-trimming methods. Tiedemann and Sorensen also reported that the chain-saw method was less tedious and less time-consuming than conventional hand-trimming methods. The chain-saw technique of trimming samples was reported to be three to four times faster than conventional hand-trimming techniques. It was stated that the chain saw was of a standard design except that carbide tips had been brazed to the cutting teeth to enhance the cutting of the soil sample.

Block samples to be tested at the site should be cut to sizes dictated by the individual tests to be performed. Samples to be used for water content determination may be broken from the corner of large block samples. Samples to be tested at the site may be coated with a thin brush coating of wax or reinforced with cheesecloth and wax, as necessary, to prevent the sample from drying or to prevent damage caused by excessive handling.

(3) *Push samplers*. Several hand-operated open- or piston-samplers are available for obtaining undisturbed samples from the ground surface as well as from the walls and bottom of pits, trenches, or accessible borings. The hand-operated open sampler consists of a thin-wall sampling tube affixed to a push rod and handle. The piston sampler is similar to the open sampler except a piston is incorporated into the design of the device. The procedures for operating these samplers are similar to the procedures

for open samplers or piston samplers in rotary drilling operations, as described in Chapter 6. Hand-operated push samplers may be used to obtain samples in soft-to-medium clays, silts, and peat deposits at depths of 6 to 9 m (20 to 30 ft) or more.

b. Disturbed samples. Disturbed samples may be obtained from test pits, trenches, or accessible borings. Disturbed, representative samples of soil are satisfactory for certain laboratory tests including classification, water content determination, and physical properties tests. For certain soils such as very soft clays or gravelly soils, undisturbed samples may be impossible to obtain. Provided that the unit weight and moisture content of the soil in place can be estimated or are known, it may be permissible to perform certain laboratory tests on specimens remolded from samples of disturbed material.

To sample a particular stratum, remove all weathered and mixed soil from the exposed face of the excavation. Place a large tarpaulin or sheet of plastic on the bottom of the test pit or accessible boring. With a knife or shovel, trench a vertical cut of uniform cross section along the full length of the horizon or stratum to be sampled. The width and depth of the cut should be at least six times the diameter of the largest soil particle sampled. Collect the soil on the tarpaulin. All material excavated from the trench should be placed in a large noncorrosive container or bag and preserved as a representative sample for that stratum. An alternative sampling procedure consists of obtaining a composite sample of two or more soil strata; if samples from certain strata are omitted, an explanation must be reported under “Remarks” on the log form. Samples obtained for determination of water content may be placed in pint glass or plastic jars with airtight covers; the sample should fill the container.

To obtain samples from quarries, ledges, or riverbank sands or gravels, use the procedures for obtaining disturbed samples which were discussed in the preceding paragraphs. Channel the face vertically to obtain samples representative of the formation. Take care to ensure that overburden or weathered material is not included as a portion of the sample.

11-4. Preservation of Samples and Test Records

a. Preservation, shipment, and storage of samples. Undisturbed samples to be tested in the laboratory must be packaged to prevent any disturbance that will affect test results. Block samples or samples obtained by the trimming and advancement technique must be marked and stored in a vertical orientation. Disturbed samples should be placed in a bag or a corrosion-resistant container and preserved as a representative sample for the particular stratum of material. If a container is used, identification of the contents should be marked directly on the exterior of the container; do not mark the lids of containers because they may be inadvertently interchanged. If the natural water content of the sample is to be preserved, the container must be waterproof. For shipment, each sample should be packaged to prevent damage, such as excessive vibrations, loss or mixing of materials, temperature extremes, or change of water content, which could affect test results. Additional details regarding the preservation of materials for shipment and storage are presented in Chapter 13 and in ASTM D 4220-83 (ASTM 1993).

b. Records. Although there is no single procedure for recording the data, the record should reflect all details of the investigation. Pertinent data, including the name of the project, job or contract number, samples obtained, tests conducted, etc., must be recorded on data sheets. The methods used for excavation along with a description of the equipment, an observation of procedures, and an evaluation of the effectiveness of excavation procedures are necessary to permit the evaluation of the overall program. The location or position of each borehole, test pit, trench, sample, or test should be clearly located horizontally and vertically with reference to an established coordinate system, datum, or permanent monument. The depth of each major change in soil character and a detailed description of each major stratum should be recorded. Be sure to note stratifications, structural and textural features, color, hardness, density, grain size, percent by volume of cobbles and boulders, etc., of the stratum. Include methods of stabilizing the excavation. Maps or sketches with accurate descriptions and photographs are extremely helpful for documenting the record of the site investigation. Each soil sample or test should be numbered. The number and type of sample containers should also be shown on the appropriate data sheet(s). If field tests are performed, a data sheet for each test must be prepared giving pertinent data such as weight, volume, density, and water content. All data sheets should be dated and signed by the crew chief or technician performing the operation. Additional guidance for the preparation of field records is given in Chapter 13.

11-5. General Safety Considerations

Several safety considerations with respect to the inspection and sampling or testing of formations exposed by excavations for test pits, trenches, and accessible boreholes or tunnels should be addressed. Although the accompanying list does not address every situation, the suggestions can be used as general guidance to develop a checklist of safety considerations for each site investigation.

- Prior to conducting any excavation, underground installations such as gas, telephone, water, and electric lines must be located and plainly staked.

- Shallow, i.e., less than 1.2 m (4 ft), test pits and trenches in stable soil can generally be excavated without support of the walls. However, a support system, i.e., sheet piling, bracing, shoring, and/or cribbing, or sloping walls is required for excavations deeper than 1.2 m (4 ft) (EM 385-1-1). The support system must be designed by a professional engineer experienced in that type of work.

- Before entering a test pit or trench, inspect the sidewalls and install cribbing or shoring or slope the wall of the excavation, if necessary. Remove loose material that could fall into the excavation.

- Provide ladders, stairs, or ramps, as necessary, to access the pit or trench. For boreholes, a cage or boatswain chair should be used to lower personnel into the hole. The chair should have two lines; the second line is used as a safety line.

- The test pit or borehole should be properly ventilated. Exhaust gases from engines should be directed away from the air intake. A means for detecting poisonous gas should also be provided.

- Groundwater (surface water) should not be permitted to accumulate in excavations. After rain-storms, excavations should be inspected by a qualified person to assess the sidewalls for possible slides or cave-ins; shoring should be added or changed, as necessary.

- To prevent a hazardous loading condition that could trigger a slide, the material excavated from a test pit or trench should be placed at a distance from the edge of the excavation not less than 1.2 m (4 ft) or the depth of the pit or trench, whichever is greater.

- Large-diameter borings or shafts should be cased. In stable soils above the groundwater table, corrugated pipe is an economical method. For deep borings or for boreholes in soft, unstable soils, thick-walled steel pipe may be required. Inspection and sampling or in situ testing of the formation may be conducted using holes cut in the wall of the pipe.

- The support system for the walls and roof of a tunnel should be designed by a professional engineer experienced in that type of work.

- Fences, barricades, covers, or warning lights should be provided around excavations, as necessary, to protect pedestrians, livestock, or vehicular traffic.

- Temporary excavations should be backfilled as soon as possible after the work has been completed.

Table 11-1
Accessible Excavations (after U.S. Department of the Interior 1986)

Accessible Excavation	Procedure	Limitations	Comments
Test pit	Excavate a rectangular or square pit by hand or power equipment. Minimum dimensions are of the order of 1 by 1-1/2 m (3 by 5 ft).	Economical limit of depth is about 6 to 9 m (20 to 30 ft) or to the water table. If deeper than 1.2 m (4 ft), support or slope the walls of the excavation.	Samples from a test pit are usually more expensive than samples obtained from conventional drilling and sampling operations. Sampling by hand may be the only method of obtaining representative samples of certain soils.
Trench	Excavate a rectangular or trapezoidal (cross section) trench by hand or with power equipment. The minimum dimension of the excavation should not be less than 1 to 2 m (3 to 6 ft) wide). The length may be extended as required.	Depth of trench is usually fairly shallow, but may be 6 to 9 m (20 to 30 ft) or to the water table. If deeper than 1.2 m (4 ft), support or slope the walls of the excavation.	Provides a continuous two-dimensional soil profile. This method is perhaps the most economical and comprehensive technique for shallow explorations of foundation, borrow, or aggregate material.
Accessible boring	Special purpose drilling equipment, such as large-diameter bucket augers, may be used to drill accessible boreholes to a depth of about 30 m (100 ft). The minimum diameter is about 0.6 m (2 ft), although a larger diameter may be required for adequate work space.	Accessible boreholes deeper than 1.2 m (4 ft) should be cased with steel pipe. Holes may be cut into the pipe to permit inspection and sampling of the sidewalls of the excavation.	If power equipment is available and the area is accessible, large-diameter boreholes can be made more rapidly and at less cost than excavating test pits by hand methods.
Tunnel	Excavate a rectangular-shaped tunnel by hand or with power equipment. Minimum dimensions are of the order of 1.5 by 2.1 m (5 by 7 ft), although the dimensions may be increased when power mucking and hauling equipment are used.	Tunneling is expensive and therefore should be used only under special conditions. The roof and walls of the tunnel require a support system.	Must provide underground lighting and ventilation system.

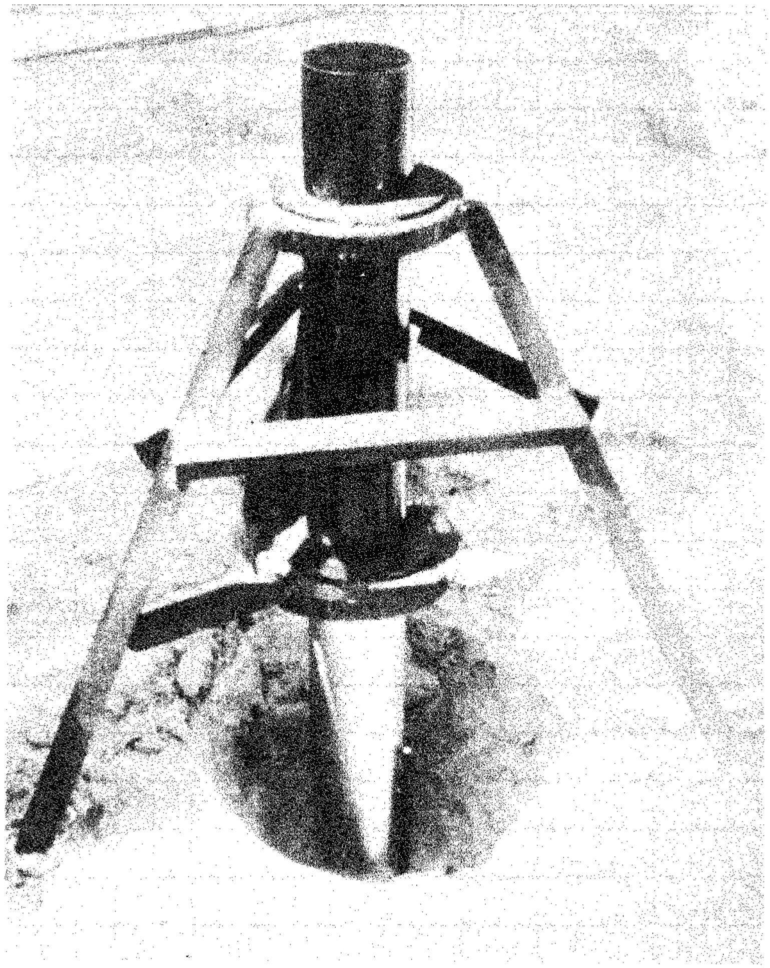

Figure 11-1. Photograph of the GEI sampler which incorporates the advanced trimming technique for obtaining a soil sample

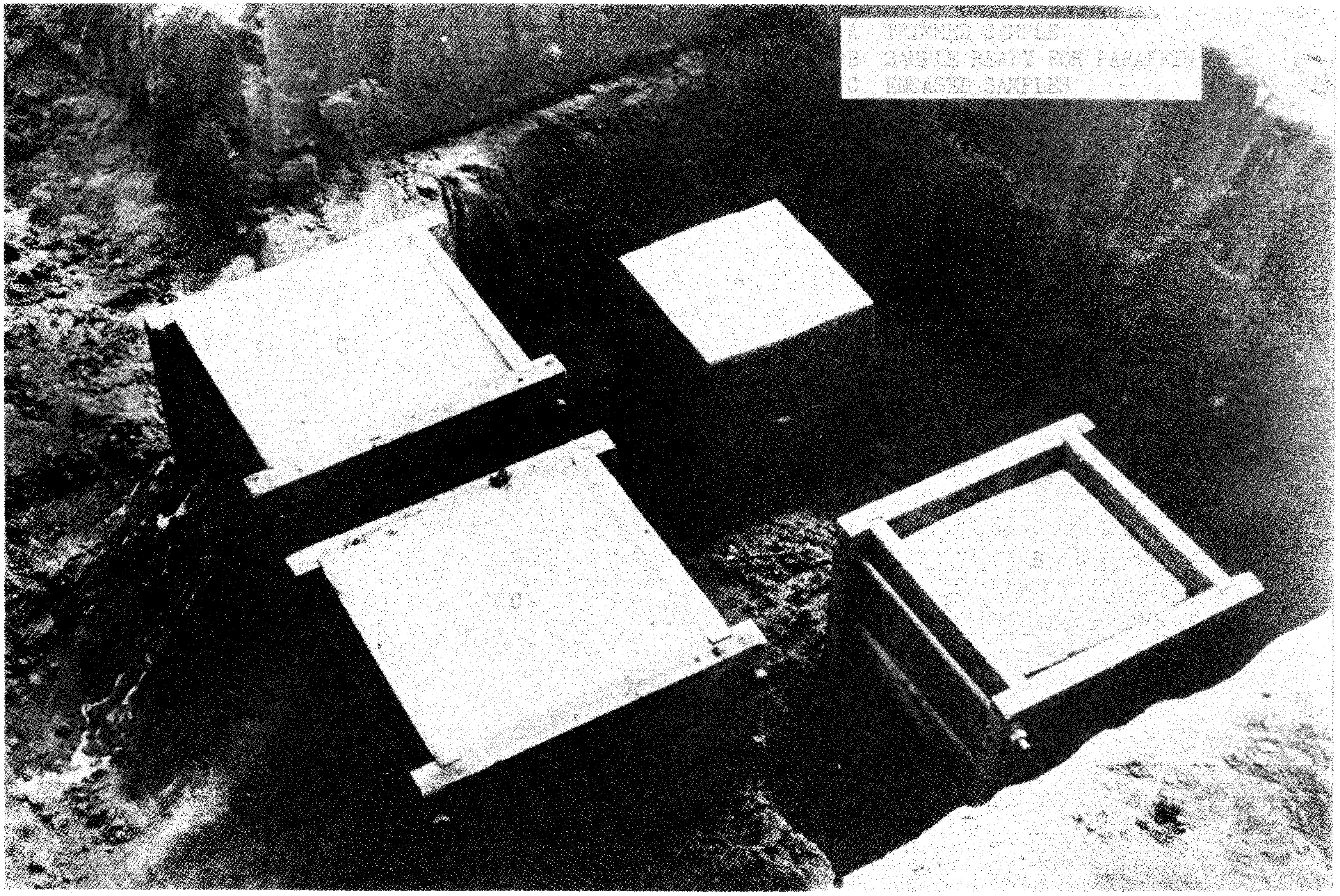

Figure 11-2. Photograph of block samples in various stages of trimming and sampling